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# Analytical and Systematic Study of Artificial Neural Network

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**Abstract -** *Artificial neural network is a neural network motivated by the biological neural network where numbers of neurons are interconnected with each other. The neurons in artificial neural network are operating and arranged in such a manner that they invigorate the fundamental construction of the neurons in the human cerebrum. The fundamental rationale behind the artificial neural network is to implement the structure of the biological neuron in a way that the whatever the function that the human brain perform with the aid of biological neural network, that thusly will the machines and frameworks can likewise perform with the assistance of artificial neural network. This paper gives a concise outline of an artificial neural network with its working, architectures, and general organization, and so forth. This paper additionally express some advantage and disadvantage , application of the artificial neural network in some most significant areas such as image processing, signal processing, pattern recognition, function approximation, forecasting based on the past data and some more.*

***Keywords*** **- Artificial Neural Network, Artificial Neuron, Activation functions, Feedforward network, Feedback Network.**

## INTRODUCTION

The biological brain is made up of billions of nerve cells that form a complex linked network (neurons). There are roughly $10^{10}-10^{11}$ neurons in a human brain. The brain is the massive and complex network system, with each neuron linked to $10^{3}-10^{5}$ other neurons. The structure of the neuron may be split into three parts: soma (cell body), dendrites, and axon. [1]

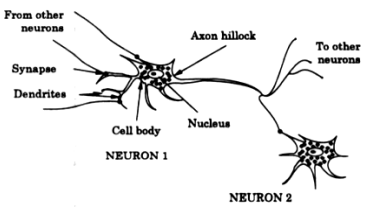


**Fig-1**: Schematic structure of Neuron [2].

The structure of a single neuron is formed by these three components. Each component or a part performs a significant role and contributes to the completion of a certain activity. Like the other cells, the cell body, also known as the soma contains the nucleus. Dendrites are the tree like nerve fibers that are connected to the cell body. The signals from the other neurons are received by these dendrites. Depending on their function, each neuron in the human brain can contain many sets of dendrites. The axon, unlike the dendrites link, it is electrically active and functions as an output channel. The axon is the neuron's transmitter, which delivers the signal to the neighboring neurons. The synapse of the neuron are the fundamental building block of brain information processing; they not only convert an input signal into a potential signal, but they also contain an experienced memory functions, allowing them to perform weighted processing on the input signal based on the memory. [1-4]

### What is Artificial Neural Network?

Artificial Neural Network designs are biologically inspired in the sense that they are made up of the elements that operate in a way similar to the fundamental biological neuron. The arrangement of artificial neurons in manner they may excite the structure of the brain. [5]

Artificial Neural Network Structure

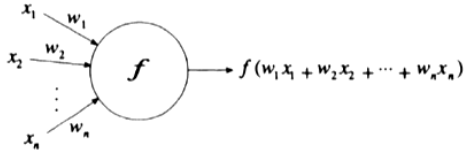


**Fig-2**. Artificial Neuron [6].

Each node receives a diverse input from other nodes through connections with accompanying weights that corresponds to the strength of the synapse. Weight is the word used in a neural network terminology to represent the strength of a link between any two neurons in the neural networks. Every neuron has the single output and a processing unit with a synaptic input connection. [3,7]

Assume that various weighted inputs are provided at the following level of specialization, as shown in figure.

The neuron output may be returned as

$$f(W_1 X_1 + ....+ W_n X_n)$$

Or

$$f\left(\sum_{i=1}^{n} W_i X_i\right)$$

*or*

$$f(net)$$

Where, $net = \sum_{i=1}^{n} W_i X_i$

Where, W is the weighted vector defined as $w = [W_1, W_2 ..... W_n]$ and x is the input vector defined as $X = [X_1, X_2 ..... X_n]$. [7,8]

**Activation functions**

The activation function is primarily used to abstract the operations of the neural network. A mathematical function that turns or converts input to the output and adds a magic to the neural network processing is known as an activation function. [9]

There are several distinct sort of activation function that is regularly employed, and a few of them are presented below.

**Step function**

It is the simplest activation function among all the activation function in the neural network.

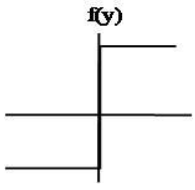


**Fig-3**: Step Function [10].

The above graphical representation depicts the step function.

Depending on whether the input signal is greater than or less than 0, the output of this function is confined to one of two values [10].

This function is defined as follows.

Output =1 when y>0 .....1. (a)

= -1 when y<0 ..... 1. (b)

Based on the function that is defined below, the two conditions are arises, Considering the first condition where input signal is greater than 0, The output will be 1, another condition is when the input signal is less than 0, then the output will be -1.

**Linear function**

Another activation function is Linear Activation function.

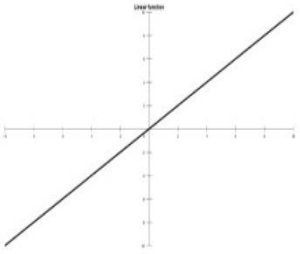

**Fig-4**: Linear function [9].

The above diagram interprets the graphical interpretation of a linear activation function. As seen in the above figure, the graph of linear activation function is a straight line.

These functions have the effect of multiplying by the constant factor to the input signal,

i.e.,

Output=K. y ..... 2

Here the K is the constant Factor and y is the signal values.

The range of the function is defined in (–infinity, +infinity), and it can be used in some network nodes where dynamic range isn't an issue.

[9,10]

**Ramp Function**

Another activation function is the ramp function. It comprises the concept of step and linear functions. The output is basically depends on the correlation of input i.e., signal with upper and lower limit. Between the upper and lower limit the function will be act as a linear function, after this restricts are reached, it will be behave as a step function [10].

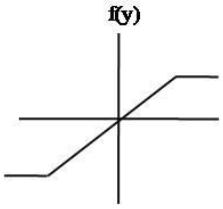


**Fig-5**: Ramp function [10].

The above graphical interpretation shows the ramp activation function. This function may be defined as follows,

Output = Max, y>upper limit. ... 3. (a)

=K. y, y< upper limit & y> lower limit ...3. (b)

=Min, y< lower limit. ...3. (c)

**Sigmoid Function**

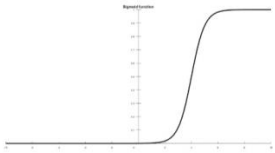

**Fig-6**: Sigmoid Function [9].

The above figure interprets the graphical representation of a sigmoid function.

A mathematical function that creates a sigmoidal curve is known as sigmoid function, because of 'S' form shape. This is the most basic and often used utilized activation method. A 'S' shaped curve can be defined using a variety of mathematical formulas, the most popular of which is the equation.

$$f(y) = \frac{1}{1+e^{-y}} \quad \text{..... 4}$$

[9,10]

**Network topology**

An artificial neural network consists of two or more artificial neurons connected to each other. Neural network topology or architecture describes the different ways in which connections can be established. [11]

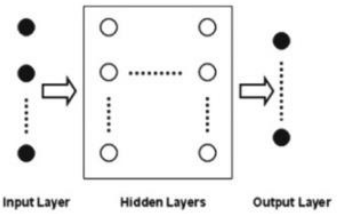


**Fig-7**: General Arrangement of Layers in Artificial Neural Network [3].

There are three distinct sorts of layers.

Input layers- This is the neural networks' starting stage. This layer is in charge of accepting data, information, or signals, and transmitting them to the next or subsequent layer for further processing. This layer does not do any computation. The primary goal of the layer is to collect the data from the outside world.

Hidden layer- This layer lies between the input and output layer. The hidden layer main job is to process or compute the data with the help of computational nodes from the input layer. In a neural network, there can be one or more hidden layers. This layer may be performs the distinct task that the other layers can't do. The internal processing in this layer is analogues to the processing that occurs in the human brain. It transmits the resultant output to the output layer through an activation function, after the processing and computing the signals fed from the input layer.

Output layer-This layer of the neural network is responsible for creating the output that arises from processing or computing conducted by the neurons in the preceding layers.

There are different of artificial neural networking topologies, such as feed forward and feedback neural network, are briefly discussed here.

**FeedForward network**

A signal flows through a neural network can be either in one-way or recursive.

We named the neural network architecture of the feedforward in the first scenario because the input signals are fed into the input layers and then processed before being transferred to the next layer. In this case, data is passed strictly from the input node to the exit i.e., output node. Single layer feed forward neural network, multilayer feedforward neural network, and the radial basis function are examples of feed forwarded networks.[9,11,12]

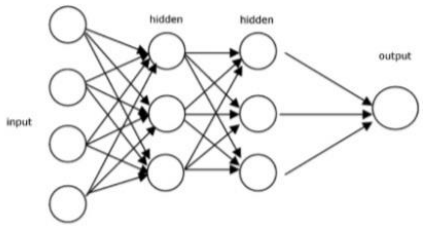


**Fig-8**: FeedForward Network [9].

**Feedback Network**

The output of one layer of the neurofeedback network is sent back to the previous layer. By introducing a loop into a network, that network can have signals that propagate in both directions. [12]

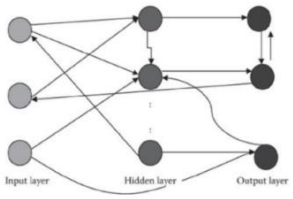


**Fig-9**: Feedback Network [12].

**Single Layer Feedforward Network**

As definition of feedforward network layer stated above, signal are go in either only in one direction from input layer to output layer in feedforwarding network. In order to create an output, a neural network fundamental structure consist of an input layer coupled with hidden layer, which is then connected to an output layer. The same reasoning as in the feedforward network is used here, with a small adjustment in the network structure. Only two layers are used in this type of feed forward network, the input layer and the output layer. The input signal is received by the input layer neuron, while the output signal is received by the output layer neurons [4]. In this paradigm, the output layer is only with computational nodes [13]. With the support of computational nodes, the output layer in these networks alone may compute a computational task. Therefore, it is termed to as single layer feed forward network.

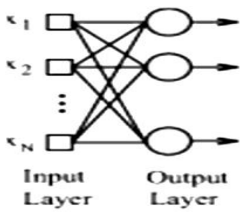


**Fig-10**: Single- Layer Feedforward Network [13].

A single layer feedforward network with n inputs and m outputs is shown in the diagram. The number of outputs in the network adhering to this design will always coincide with the number of neurons, as shown in the figure. Pattern classification and linear filtering problems are common applications of these networks. [14]

**Multilayer feed forward Network layer**

This network has a numerous layer, including a hidden layer that performs a valuable intermediate calculation before sending the input to the output layer as opposed to the single feedfoward network layer design with few similarities. The network units are organized in layers, including an input layer, one or more hidden layer, and an output layer in a sequential manner [13].

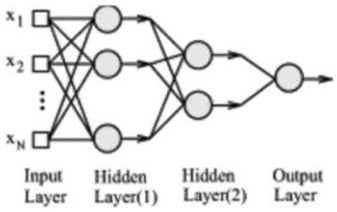


**Fig-11**: Multi-layer Feedforward Layer [13].

The above figure depicts the feedforward network made up of input layer and middle layer i.e., (hidden or computational layer) and the output layer that reflect the problem output values being analyzed.

They are used to solve a wide range of problems including those involving function approximation, pattern classification, process control, optimization, robotics and so on [14].

**Recurrent Neural Networks**

The design of this network differ from that feedforward networks [4].

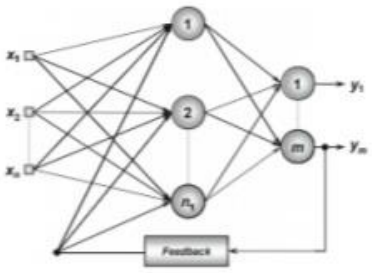

**Fig-12**: Recurrent Network Layer [14].

The output of this function of a neurons is used as feedback inputs for other neurons in the network.

The network feedback function suitable for dynamic information processing i.e., it can be used for time varying systems, time series forecasting systems, identification and optimization, process control and many more. One of the input signals of a perceptron network with feedback to the middle layer as shown in figure above. [14]

**Characteristics of Neural Network**

The neural network has mapping capabilities, which means it can convert input patterns to output patterns.

The neural network has the capacity to generalize, which means it can forecast new findings or outcomes based on the previous trends.

Because the neural network are resilient and fault resistant, they can be referred to as full patterns instead of incomplete, partial, or noisy patterns.

The input is processed in parallel and in a dispersed manner by the neural network.

[4,5]

**Applications**

Image Processing and Computer vision includes image mapping, preliminary processing, segmentation and analysis, computer vision, image compression, stereo vision and processing, and interpretation of time varying visuals.

Signal Processing: Seismic, signal analysis and morphology are incorporated into signal processing.

Pattern Recognition includes features such as feature extraction, radar analysis and classification, speech recognition and interpretation, biometric authentication such as fingerprint indentification, character recognition and handwriting analysis.

Health: Breast cancer, cytology, egg analysis and electrocardiogram, prosthetic designing, optimize transit time, reduce hospital cost, improve hospital quality, consultation on new energy tests, are just a few of the medical issues addressed.

Function Approximation- The problem of learning to design a function that generate nearly the same output from input vectors has been modeled based on the available training data.

Forecasting- There are several real-world issues in which future occurrences must be forecasted using historical data. One such work is forecasting the behavior of stock market indices.

[5,8,15]

**Advantages of Artificial Neural Network**

A neural network can complete a task that a linear programme can't.

When one of the neural network element fails, the rest of the network can function normally because to their parallelism.

Can manage data that is noisy or incomplete.

Because of their capacity to learn, they do not require programming, making artificial neural networks straightforward to use in a variety of applications.

Artificial neural networks can deal with situations when there isn't enough data or information.

Artificial neural network has fast processing Speed.

[11,16,17]

**Disadvantages of Artificial neural networks**

Large neural network need a long processing time.

To train an artificial neural network, you will need a large data collection, and they have a tendency to over fit.

Before they can operate on, they must be trained.

It's tough to decipher their internal structure because of their black-box character and radial basis function.

Even if data is incorrect, artificial neural network always produce accurate results.

[11,16,17]

**Conclusion**

In this paper, we have learned about the fundamental of artificial neural network, its working, architectures, attributes and a few applications to some critical regions. As the progressions of innovation are developing step by step, the significance of Artificial intelligence is subsequently increments. In current days, various investigations have been created, and specialists are kept on propelling their insight in these fields of artificial intelligence. For the future perspectives, there ought to be progression in fostering a calculations and strategies to conquer the restrictions of artificial neural networks.

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